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The impact of air pollutants on the hospitalization of cardiovascular patients in the emergency room: A ten-year study

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ABSTRACT

Background: There are various risk factors for the hospitalization of cardiovascular patients in the emergency room. Air pollution is one of the risk factors for cardiovascular diseases. This study aimed to determine the impact of air pollutants on the hospitalization of cardiovascular patients in the emergency room of a selected military heart hospital. *Methods:* This is a time-series study. we used the data of cardiovascular patients and the data of air pollutants. We checked the correlation of air pollutant variables with the daily number of cardiovascular patients admitted to the emergency room with Spearman's correlation test. *Results:* We evaluated 148,210 cardiovascular patients, and 53.51% were female. The number of cardiac patient admissions in the emergency department increased annually from 2013 to 2022. Air pollutant variables showed a rising trend between 2013 and 2022. There was a significant positive correlation between the changes in the number of cardiovascular patients admitted to the emergency room and the changes in CO, SO2, NO2, PM10, and PM2.5 variables. The Poisson Regression model implemented using air pollutants predicts 3% of the trend of changes in the number of cardiovascular patients hospitalized in the emergency room in a significant way (0.0001). *Conclusion:* The results of the present study showed that air pollutants are among the risk factors for the hospitalization of cardiovascular patients in the emergency room. With the increase in the concentration of CO, SO2, NO2, PM10, and PM2.5 pollutants, the number of cardiovascular patients in the emergency department of the investigated hospital has increased significantly.

Keywords: Cardiovascular disease, cause of hospitalization, epidemiology, referral, COVID-19

1. INTRODUCTION

Air pollution is a main global health threat (Thurston et al., 2016; Kim et al., 2021; Ljungman et al., 2019). As such, it requires the attention of policymakers, mainly those in the health sector. Over the past two decades, there has been an increased focus on air pollutants (Miller and Newby, 2020). Air pollution is associated with numerous health problems, such as exacerbating heart and lung conditions and raising the risk of asthma, heart attacks, strokes, and premature death (Kim et al., 2021). The World Health Organization's report states that air pollution accounts for 6.7% of global deaths (Mcevoy et al., 2010). The number of deaths caused by air pollutants is rising, mainly in developing nations. Lifetime exposure to air pollution significantly decreases life expectancy. The decrease ranges from an average of 3-6 months in less polluted countries like the United Kingdome and the United States of America to 1-2 years in countries with high levels of air pollution (Joshua et al., 2018).

Ambient air pollutants are a combination of gases and suspended particles. The most important pollutants are particulate matter (PM), including PM10 and PM2.5, sulfur dioxide (SO2), nitrogen oxides (NOX), ozone (O3), and carbon monoxide (CO) (Hansel et al., 2016; Brook et al., 2010). Air pollution is a significant cause of morbidity and mortality worldwide. Atherosclerotic cardiovascular diseases, including ischemic heart disease (IHD) and stroke Roth et al., (2020), Brauer et al., (2021), are responsible for over 50% of these deaths. Air pollution effectes on approximately 90% of the world's population health situation (Montone et al., 2023). Air pollution and air pollutants contribute to increased mortality and hospitalization rates for cardiovascular diseases, mainly among high-risk groups (Moradgholi et al., 2019).

Air pollution has several effects on cardiovascular patients and is associated with complications such as an increased probability of hospitalization, re-hospitalization, and premature death (Warburton et al., 2019). Air pollutants negatively affect the cardiovascular system through numerous biological mechanisms (Berglind et al., 2009; Delfino et al., 2010). Air pollutants, including urban PM, impact various aspects of the cardiovascular system, leading to increased cardiovascular complications and mortality (Millier and Newby, 2020). Despite efforts to reduce the burden of cardiovascular diseases, such as smoking cessation, blood pressure control, and management of type 2 diabetes, cardiovascular diseases remain a leading cause of death.

Therefore, in recent years, there has been a serious pursuit of new methods to reduce the burden of cardiovascular diseases (Montone et al., 2023). Cardiovascular diseases are one of the most important causes of death in the world (Huang et al., 2018). Cardiovascular diseases are a leading cause of death worldwide, responsible for 31% of all deaths. They are also a significant cause of disability globally, with over 80% of the burden occurring in developing countries (Derakhshan et al., 2021; Sarrafzadegan and Mohammmadifard, 2019). The risk of cardiovascular diseases has increased due to the growing elderly population (Janjani et al., 2023). Cardiovascular diseases are a leading cause of morbidity and mortality in Iran, accounting for 43% of non-communicable disease-related deaths. As a developing country, Iran will facing an old population soon, which may exacerbate this issue (Derakhshan et al., 2021; Sarrafzadegan and Mohammmadifard, 2019).

The population will get old at the end of the forecast period until 2042, with 19 to 23 percent being over 60 years old in all three scenarios. Like the rest of the world, Iran is experiencing a rapid increase in the aging population, which in turn increases the risk of cardiovascular diseases (Janjani et al., 2023). This study aims to conduct an epidemiological investigation of the hospitalization process of cardiovascular patients in the emergency room of a selected military hospital between 2013 and 2022. Previous studies have shown the effect of air pollution variables on cardiovascular diseases. However, there are few studies on this topic in Iran, mainly in military hospitals. Therefore, we conducted this study to fill this knowledge gap.

2. METHODS

This study is a time-series investigation conducted between 2013 and 2022. We used data from a selected military cardiac hospital in Tehran and information from meteorological stations of the Head Office of the Tehran Province Environmental.

Study population

This study examined all cardiovascular patients admitted to the emergency room of a selected military heart hospital in Tehran between 2013 and 2022.

Data integration

The variables analyzed in this study include the number of daily admissions to the emergency room of the selected military heart hospital, as well as levels of air pollutants such as carbon monoxide (CO), tropospheric ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), particulate matter 10 (PM10), and particulate matter 2.5 (PM2.5). The data was extracted using Excel and merged after checking the details. We collect data on air pollutants based on the living place of each patient.

Data analysis

This study presents a histogram showing the hospitalization trend of cardiovascular patients by gender and age group from 2013 to 2022. Additionally, a linear diagram displays changes in average carbon dioxide and carbon monoxide pollutants from 2013 to 2022. We used mean, standard deviation, median, and interquartile range indicators for descriptive analysis. To examine the correlation between air pollutant variables, the number of daily hospital emergency admissions, and the correlation between air pollutant variables, we used Spearman's correlation. Also, to investigate the simultaneous effect of air pollutant variables on the number of daily cardiovascular patients admitted to the emergency room, Poisson regression was used, which is a linear model. All analyses were conducted at 0.05 significance using SPSS Version 16 software.

3. RESULTS

This study examined 148,210 cardiovascular patients in the emergency room of a selected military hospital from 2013 to 2022 over 3,725 days. Of these patients, 68,907 (46.49%) were male and 79,303 (53.51%) were female. Most patients, 98,200 (66.26%), were under 65 years old, while 50,010 (33.74%) were over 65 years old. Throughout the study, the number of female patients in the emergency room exceeded that of male patients. The admission process for cardiac patients at the selected military cardiac hospital has increased from 2013 to 2019, with a decrease during the COVID-19 pandemic in 2020. However, admissions have been rising again in 2021 and 2022, as shown in (Chart 1 and Chart 2).

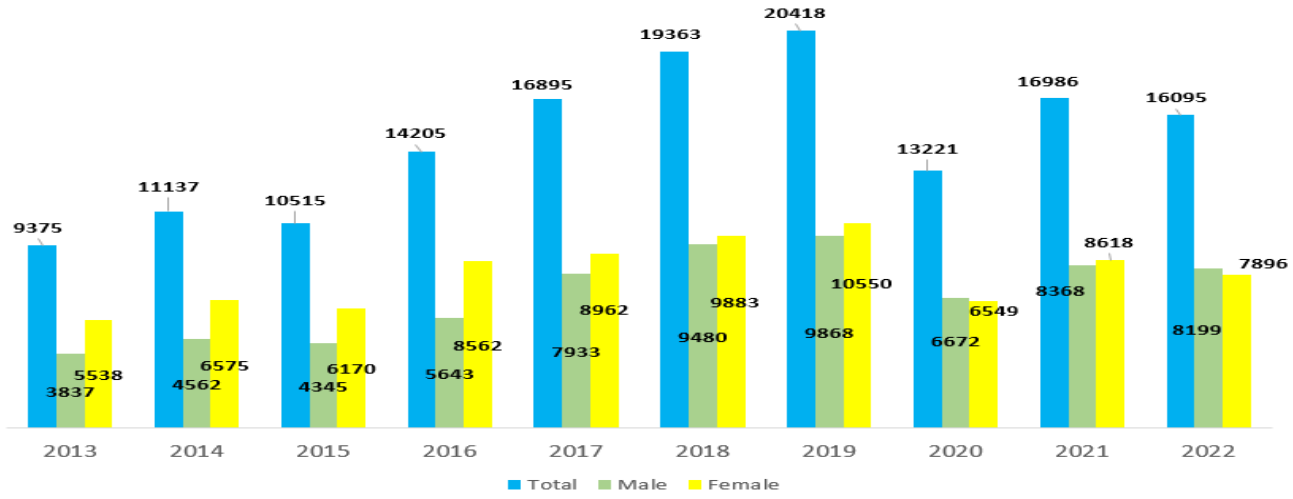


Chart 1 Gender distribution of cardiovascular patients in the emergency room of a selected military hospital between 2013 and 2022

During the study period, we extracted daily air pollutant concentrations from meteorological stations of the Tehran Environmental Protection Organization. The mean and standard deviation of CO, O3, NO2, SO2, PM10, and PM2.5 pollutants are in (Table 1). From 2013 to 2022, the average levels of air pollutants, including O3, CO, NO2, SO2, PM10, and PM2.5, rose in the studied area. Since 2018, the values of almost all air pollution variables in the studied area have significantly increased, as shown in (Table 2).

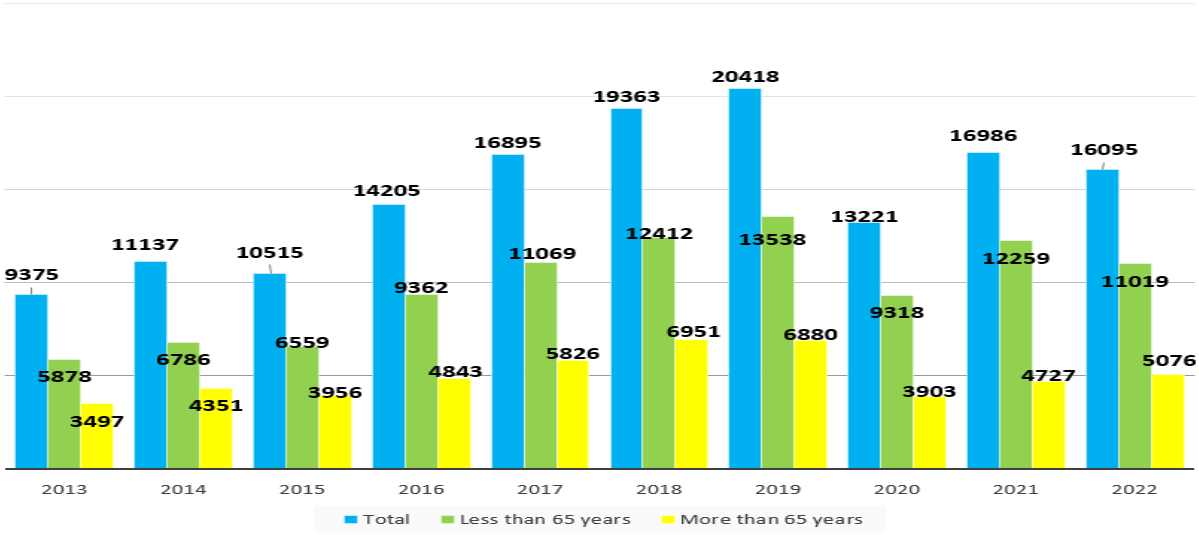


Chart 2 Age distribution of cardiovascular patients in the emergency room of a selected military hospital from 2013 to 2022

Table 1 Average distribution and standard deviation of environmental variables from 2013 to 2022 in the Shemiranat region

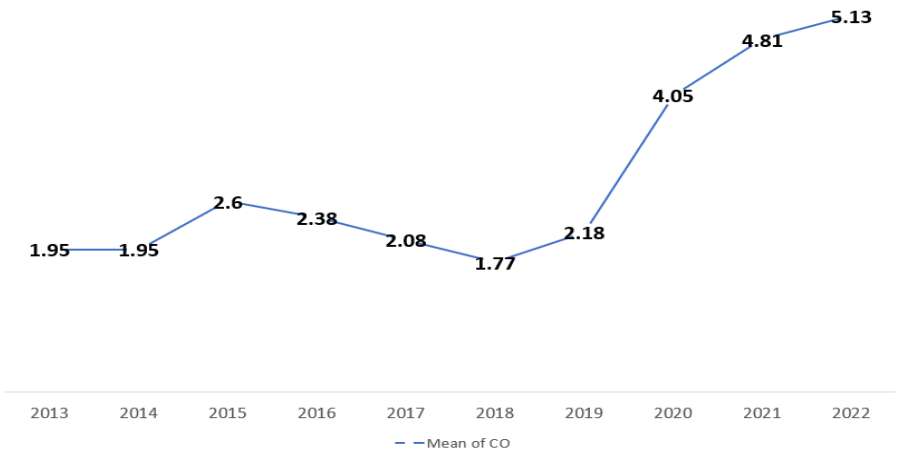
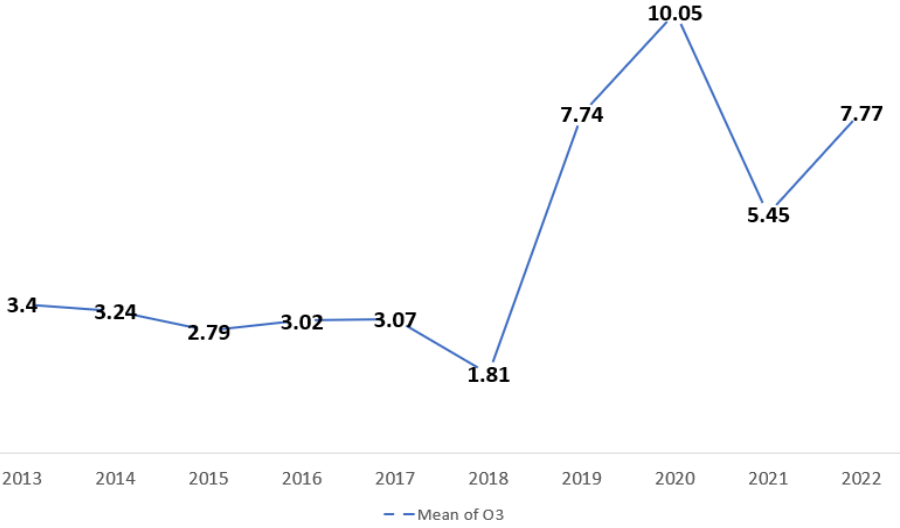
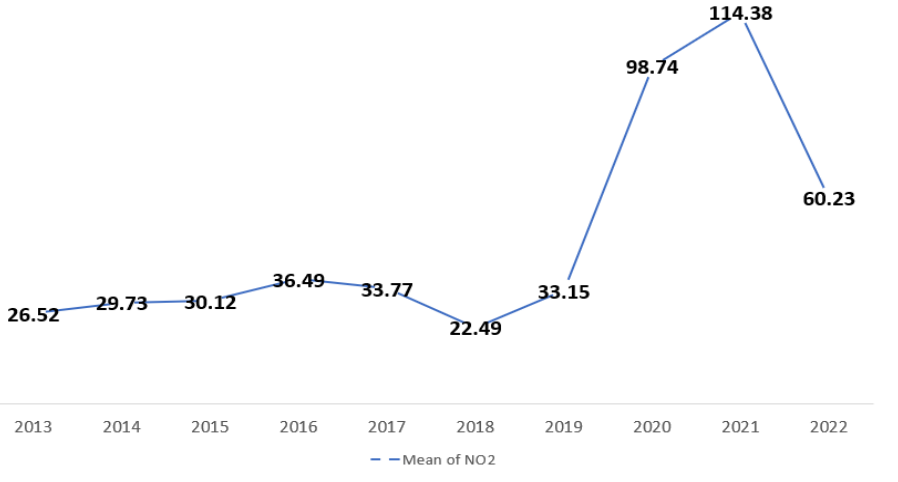
Study period	Row	Variable	Mean (standard deviation)
2013-2022	1	CO ppb	2.97 (1.78)
	2	O3 ppb	4.84 (10.06)
	3	NO2 ppb	49.28 (38.18)
	4	SO2 ppb	13.68 (7.77)
	5	PM10 µg /m3	33.20 (47.13)
	6	PM2.5 µg /m3	53.53 (52.33)

We evaluate the correlation between air pollutant variables and the number of patients admitted to the emergency room of the selected military cardiovascular hospital, and found that there was a significant correlation (p-value < 0.05) between the variables CO, NO2, SO2, PM10, and PM25 and the number of cardiovascular patients admitted to the emergency room. The number of admitted cardiovascular patients to the emergency room of the selected military hospital under study increased with the rise in CO, NO2, SO2, PM10, and PM25 values (Table 3).

The correlation of synoptic and air pollutant variables with the number of patients hospitalized each day in the emergency room of a selected military hospital. Table 4 shows significant positive correlations between all air pollutant variables. It indicates that as the value of each air pollutant variable increases, so does the value of the other air pollutant variables.

In the Poisson Regression test, a model significantly (p-value = 0.0001) predicts the trend of changes in the daily number of cardiovascular patients admitted to the emergency department. Among the investigated air pollutant variables, only the O3 variable had no significant relationship (p-value = 0.086), and other air pollutant variables in the model also had a meaningful relationship (p-value < 0.05) with the daily number of cardiovascular patients admitted to the emergency department. This model predicts 3% (Pseudo R squared = 0/03) of the changes in the daily number of cardiovascular patients hospitalized in the emergency room (Table 5).

Table 2 Changes in air pollutant variables between 2013 and 2022

Row	Variable	Changing Procedure
1	CO	
2	O3	
3	NO2	

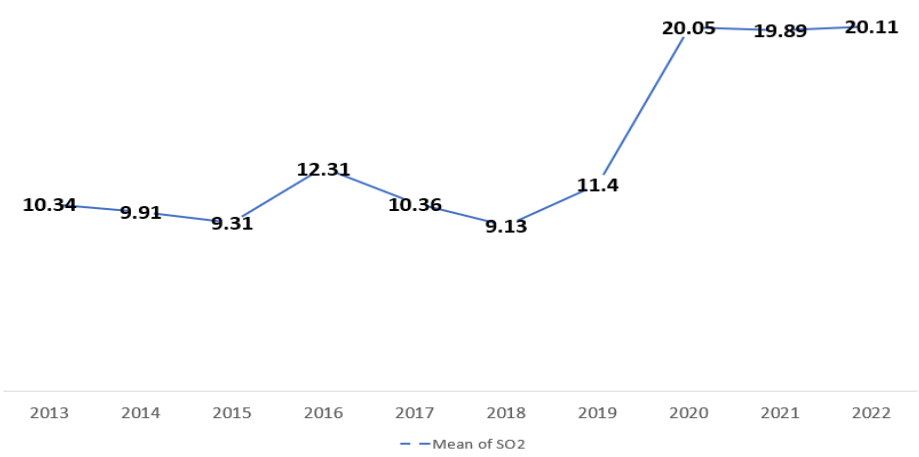
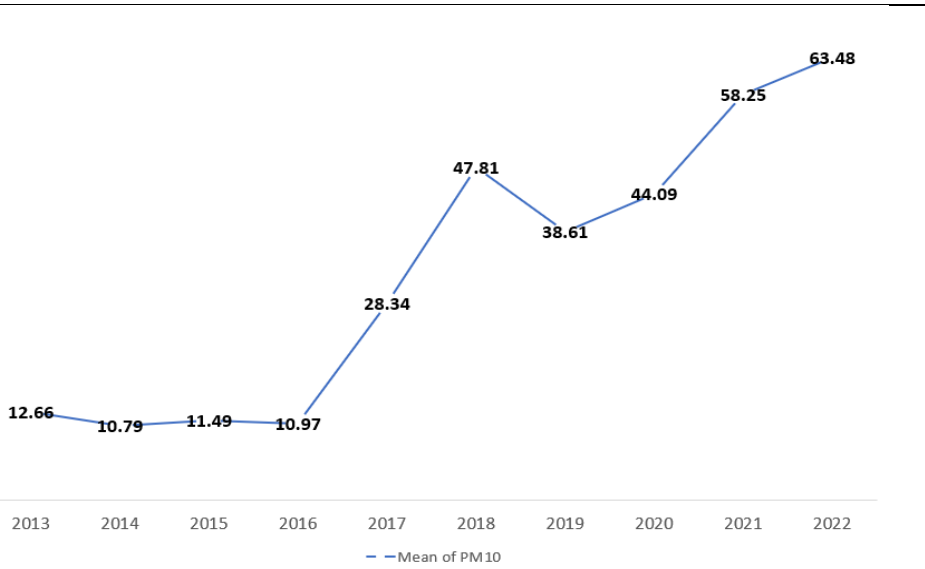
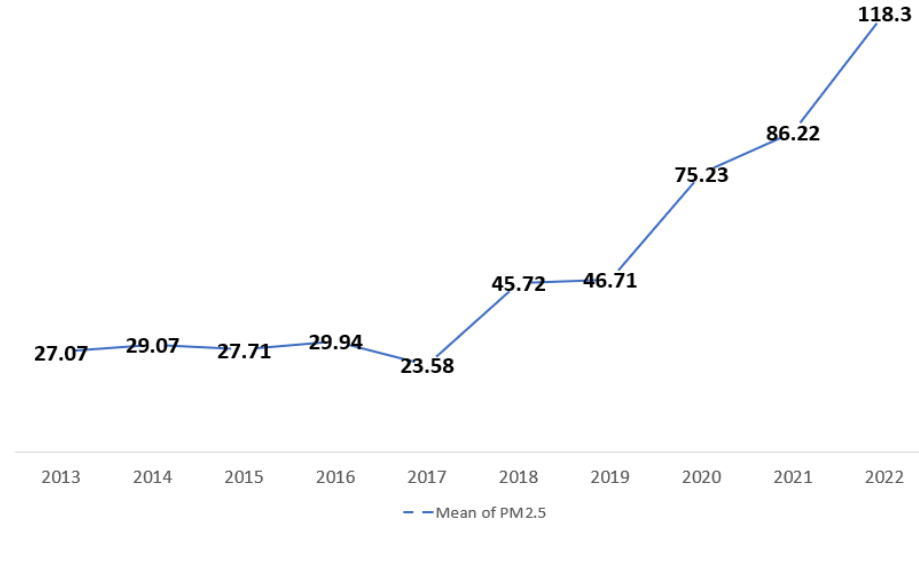
4	SO2	
5	PM10	
6	PM2.5	

Table 3 Correlation of synoptic and air pollutant variables

Row	Variables	r	p-value
1	CO	0.082	0.001
2	O3	0.014	0.388
3	NO2	0.110	0.001
4	SO2	0.107	0.001
5	PM10	0.116	0.001
6	PM2.5	0.097	0.001

Table 4 Investigating the correlation of air pollutant variables with each other between 2013 and 2022

Row	Variables	Pollutant variables	r	p-value
2	CO	O3	0.141	0.001
3		NO2	0.758	0.001
4		SO2	0.776	0.001
5		PM10	0.597	0.015
6		PM2.5	0.743	0.001
7	NO2	SO2	0.711	0.001
8		PM10	0.619	0.001
9		PM2.5	0.658	0.001
10	SO2	PM10	0.567	0.001
11		PM2.5	0.707	0.001
12	PM10	PM2.5	0.756	0.001

Table 5 Investigating the effect of air pollutant variables on the hospitalization of cardiovascular patients in the emergency room using Poisson Regression.

Row	Variable	Estimate	Standard error	Standard error 95% confidence interval	Z score	p-value	VIF	R2 with other variables
1	Co	- 0.014	0.002	- 0.018 - - 0.01	6.636	0.0001	1.99	0.49
2	O3	0.0004	0.0002	- 7.12 – 0.0001	1.715	0.086	1.02	0.02
3	NO2	0.0008	9.148	0.0006 – 0.001	8.986	0.0001	1.84	0.45
4	SO2	- 0.001	0.0004	- 0.0002 - - 0.0007	3.539	0.0004	1.91	0.47
5	PM10	0.001	6.393	0.0011 – 0.0014	20.19	0.0001	1.26	0.20
6	PM2.5	0.0004	5.749	0.0003 -0.0005	7.227	0.0001	1.61	0.37

4. DISCUSSION

The study found a significant positive correlation between the number of cardiovascular patients admitted to the emergency room of the selected military heart hospital and air pollutants, including CO, SO2, PM10, and PM2.5. It suggests that an increase in the concentration of these pollutants is associated with a significant increase in the number of cardiovascular patients admitted to the emergency room. In 2015, Mohammadi and her colleagues reported that all air pollutants have a significant relationship with cardiac deaths. However, CO had the highest correlation of 0.41. In 2017, Abdul Azimi and colleagues reported a significant positive

correlation between air pollutants and the number of cardiovascular patients visiting the hospital. The correlation coefficient showed the highest amount of correlation for atmospheric pollutants PM10 (0.165), SO2 (0.203), and CO (0.113).

In 2021, Kim et al., (2021) reported that exposure to SO2 for one month was associated with a 1.36-fold greater likelihood of ischemic heart disease. Additionally, exposure to SO2, O3, and PM10 for one year was associated with 1.58, 1.53, and 1.14 times higher odds of ischemic heart disease (Kim et al., 2021). In a 2018 study by Zhen et al., (2018), they reported that PM inhalation affects heart rate, blood pressure, vascular tone, blood coagulation, and the progression of atherosclerosis. Possible molecular mechanisms of PM-induced cardiovascular diseases (CVDs) include direct toxicity to the cardiovascular system or indirect damage by causing systemic inflammation and oxidative stress in the circulation.

According to a meta-analysis study conducted in 2022, the evidence strongly suggests a link between exposure to ambient air pollution and mortality and morbidity from CVD, stroke, hypertension, and ischemic heart disease (IHD) in both the short and long term. The study found that short-term exposure to PM2.5, PM10, and NOx consistently increased the risk of hypertension, myocardial infarction (MI), and stroke (fatal and nonfatal). Long-term exposure to PM2.5 strongly associated with an increased risk of atherosclerosis, myocardial infarction, hypertension, and stroke mortality. This comprehensive review provides strong evidence that higher levels of ambient air pollution increase the risk of cardiovascular disease, mainly mortality from cardiovascular disease, stroke, and ischemic heart disease (IHD) (De-Bont et al., 2022).

A 2019 study by Chris and colleagues reported significant associations between fine particles and cardiovascular disease (hazard ratio (HR) per 10 μg/m3 = 1.13), ischemic heart disease (HR = 1.16), and cerebrovascular disease (HR = 1.15). The study also found significant associations between NO2 and cardiovascular disease (HR per 10 ppb = 1.06) and ischemic heart disease (HR = 1.08) (Lim et al., 2019). A 2019 study in Lanzhou, China, reported a positive correlation between particulate matter concentration (PMC) and daily mortality rates from cardiovascular disease, cerebrovascular disease, and ischemic heart disease. Furthermore, an increase in PM10 concentration associated with higher mortality rates from cerebrovascular and ischemic heart diseases. The most significant effects of PMC on cardiovascular and ischemic heart diseases observed at lag 0. A 10 μg/m3 increase in PMC concentration resulted in a 0.47% and 0.85% increase in cardiovascular mortality and morbidity, respectively. It was associated with cardiac ischemia.

The study revealed that elevated levels of atmospheric PM (PM2.5, PMC, and PM10) in Lanzhou increased mortality from cardiovascular disease. Notably, the health impact of high concentrations of PM2.5 is more significant than that of PMC and PM10 (Wu et al., 2019). In a 2020 study, researchers reported a significant correlation between the average concentration of NO2, CO, and PM pollutants and the mortality rate of patients diagnosed with cardiovascular problems. The study concluded that air pollutants, mainly NO2, increase the risk of death due to cardiovascular and respiratory problems (Sarizadeh et al., 2021). Another study conducted in Ahvaz in 2019 reported a significant increase in cardiovascular hospital admissions for both the total and female population concerning O3. Hospital admissions for cardiovascular disease significantly increased in the total population, as well as in gender and age groups associated with NO2 and NO.

Additionally, in the 65-74-year-old population concerning CO, they reported a significant increase in hospital admissions for cardiovascular disease. Furthermore, hospitalizations for cardiovascular disease significantly associated with SO2. The study confirmed the short-term harmful effect of air pollution on cardiovascular complications in Ahvaz city (Dastoorpoor et al., 2019). According to a study by Hamanaka and Mutlu, (2018) chronic and acute exposure to PM pollutants increases the risk of developing and worsening heart disease. The study highlights that PM is an important endocrine disruptor, and it can cause metabolic diseases such as obesity and diabetes, known as risk factors for cardiovascular diseases (Hamanaka and Mutlu, 2018). Numerous studies have indicated that air pollutants, mainly suspended particles, pose a risk of disease and exacerbation in cardiovascular patients, as well as an increased risk of hospitalization (Pothirat et al., 2019; Phosri et al., 2019; Bourdrel et al., 2017; Fiordelisi et al., 2017).

In Patel et al., (2016) and colleagues reported that air pollutants have a molecular-level impact on the heart, blood vessels, and blood. They cause oxidative or pro-inflammatory stress responses, autonomic nervous system imbalances, and the direct penetration of harmful compounds into the tissue. Exposure to PM pollutants (PM10 and PM2.5) can lead to dysfunction of cardiovascular cells and biological processes, resulting in an increased prevalence of cardiovascular diseases such as atherosclerosis, high blood pressure, heart attack, thrombosis, and limitation of heart valve movement (Patel et al., 2016). These studies were consistent with our study and demonstrated the significant impact of air pollutants, mainly PM 10 and PM 2.5, on cardiovascular diseases, leading to increased hospitalization and mortality rates among cardiovascular patients.

This study examines the trend of carbon dioxide pollutants between 2013 and 2022 and its correlation with the admission of cardiovascular patients to the emergency room. The data shows a consistent increase in carbon dioxide pollutants and a corresponding increase in cardiovascular patient admissions. This study examines the trend of carbon dioxide pollutants between 2013 and 2022 and its correlation with the admission of cardiovascular patients to the emergency room. This study examines the trend of carbon dioxide pollutants between 2013 and 2022 and its correlation with the admission of cardiovascular patients to the emergency room.

However, in 2020, there was a decrease in admissions, likely due to the COVID-19 pandemic and reduced traffic, resulting in lower exposure to air pollutants. A 2021 study reported that COVID-19-related quarantines affected reducing airborne pollutants, leading to a possible decrease in cardiovascular events (Wolhuter et al., 2021). The global COVID-19 pandemic resulted in the implementation of quarantines and a significant reduction in road and air travel, which led to a decrease in air pollution (Giani et al., 2020). From January to April 2020, hospital admissions for acute myocardial infarction (AMI) in Northern California decreased by 48%. Also, a similar reduction in both ST-segment elevation MI and non-ST-segment elevation MI accompanied this decrease (Solomon et al., 2020).

In 2020, the hospital admissions for acute myocardial infarction (AMI) reduced in Milan, Italy. However, it was in non-ST-segment elevation MI (Stefanini et al., 2020). One theory is that patients with chest pain and symptoms of AMI are less likely to visit hospitals due to fear of contracting COVID-19 (Li et al., 2019). The COVID-19 pandemic reduced travel and increased time spent indoors, which may have contributed to this trend. Also, face masks during the COVID-19 pandemic have been shown to reduce PM2.5 inhalation and lower the risk of cardiovascular events (Giani et al., 2020).

5. CONCLUSION

This study concludes that air pollutants, such as CO, SO2, NO2, PM10, and PM2.5, are risk factors for exacerbating cardiovascular symptoms and emergencies. The number of cardiovascular patients admitted to the emergency room of the selected military heart hospital under our study has significantly increased with the rise of air pollutant variables, including CO, SO2, NO2, PM10, and PM2.5. Managment of heavy traffic on days can effectively reduce CO, SO2, NO2, PM10, and PM2.5 pollutants at their highest daily levels, which reduce the number of heart patients in the emergency room. If the trend of rising air pollutant variables continues in the coming years, an increase in the number of heart patients admitted to hospitals is obvious. Health officials should consider using data on air pollutant variables when planning emergency room requirements. Combining air pollutant variables with physiological and lifestyle variables can more accurately predict the changes in the number of cardiac patients referred to the emergency room.

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Author Contributions

SM suggested the study idea. AY and SM designed this study. JH provided, collected and checked the data. AY and JH done the data analysis. JH written an early version of the article. All authors participated in revising the text of the article and preparing the final version.

Ethical approval

We conducted this study after obtaining permission from the Research Council and the approval of the Ethics Committee of Baqiyatallah University of Medical Sciences with ethics code IR.BMSU.REC.1401.1401.109 and project code number 401000238. During the study, patient names and personal information kept confidential. Anonymous and confidential information was collected and analyzed collectively. We shared the study results with the study's beneficiaries.

Informed consent

Not applicable.

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This study has not received any external funding.

Conflict of interest
The authors declare that there is no conflict of interests.

Data and materials availability
All data sets collected during this study are available upon reasonable request from the corresponding author.

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